drift for transition

report

Buurtbatterij

A neighbourhood battery and its impact on the Energy Transition

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Author
Antonia Proka

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Author

Antonia Proka
proka@drift.eur.nl
www.drift.nl

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TRAPESES

Transition Patterns Enabling Smart Energy Systems (TRAPESES) explores how different forms of organisation and cooperation may contribute to the acceleration of a desired energy transition in the country. TRAPESES is set against the background of the societal energy transition in which disruptive innovations take place, companies are forces to split up, policy shifts occur and renewables are breaking through, supported by a fast growing number of cooperatives. The project is both theoretically and practically engaging with this transition context to simultaneously develop our scientific understanding of transitional dynamics and the role of agency in these, as well as to impact the transition itself.

DRIFT

DRIFT (Dutch Research Institute for Transitions) at the Erasmus University Rotterdam, the Netherlands, is an internationally oriented institute that combines cutting edge transdisciplinary research on sustainability transitions, policy, governance and innovation with close cooperation with policy and business to further sustainable development in practice. DRIFT is a leading institute in terms of the development and conceptualisation of transition management theory and practice. It combines academic and applied research with consultancy, education, training and societal engagement. Through its research DRIFT aims to advance our understanding of the dynamics and mechanisms of sustainability transitions and develops experimental governance interventions to influence their speed and direction.

TRAPESES

NWO Nederlandse Organisatie voor Wetenschappelijk Onderzoek

alliander

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1. Introduction

While the potential of energy storage to transform the grid has been discussed for long, it has taken years for energy storage systems to gain a legitimate position in the discussion about the actual deployment of the electricity grid and its future. Its advocates argue that energy storage may improve the working conditions and the stress-resistance of the grid, making it more secure, reliable and responsive. Storage systems, especially battery storage systems that have fast response, quick deployment time and high scalability, offer outstanding properties to meet tasks like frequency control, capacity or voltage support, presenting themselves as promising assets for grid services.[1] Allowing the shift of electricity at off peak times, batteries help reduce the congestion and the energy losses on the grid. Energy storage solutions may thus extend the life-span of the existing infrastructure, by either postponing or entirely avoiding the investment in transmission/distribution system upgrades.[2] And the value of these ancillary services to the electricity grid is expected to increase further.[3]

At the same time, energy storage systems are used to increase the local self-consumption of decentralised generation. As a result, the amount of power obtained from the grid can be lowered, which in turn leads to a decrease of the electricity bill. In fact, it has been suggested that combined with a battery system the self-consumption of electricity produced by a household solar system may increase from about 30% without storage to around 60-70%.[4] At present, where the right regulatory structure is in place, like for instance in Germany, or in areas with high electricity prices, excess of solar resources and relatively low grid feed-in remuneration, like in Australia, significant battery storage with regard to new PV installations is taking place.[1]

It has been argued that when a battery owner offers the service of his/her batteries to other users, the net value of the overall system could almost double.[5] Furthermore, when an independent operator, like an Energy Service Company, manages the battery, the return of investment increases, at least slightly, but more importantly larger battery sizes become more relevant, creating an additional investment incentive due to higher workload, more flexibility and, consequently, increased income opportunities. Research has also shown that when a battery is shared within a community, its levelised cost for communities of up to 100 homes drops by 37% as compared to single-home residential battery systems in a projected 2020 scenario in the UK. [6] Therefore, a shared community energy storage system appears to be an interesting asset for a number initiatives like renewable energy cooperatives.

Nonetheless, energy storage development still faces challenges related to both the technological and the organisational features of the concept. As regards technology, the increase of the capacities and efficiencies of the existing technologies is of significant priority. On the organisational side, studies in Europe and US demonstrate that the provision of a single

[1] IRENA, 2017. Electricity Storage and Renewables: Costs and Markets to 2030, International Renewable Energy Agency, Abu Dhabi.

[2] EUROBAT, 2016. Battery energy storage in the EU: Barriers, opportunities, services and benefits.

[3] See Appendix B for more on the value of balancing markets.

[4] Fraunhofer ISE, 2014. Recent Facts about Photovoltaics in Germany, Compiled by Dr. Harry Wirth, Freiburg, Germany.

[5] Lombardi & Schwabe, 2017. Sharing economy as a new business model for energy storage systems. Applied Energy, 188, 485-496.

[6] Parra et al, 2015. Optimum community energy storage system for PV energy time-shift. Applied Energy, 137, 576–87.

service (e.g. kWh) was not sufficient to make the storage scheme cost effective; services such as frequency stabilisation and voltage stabilisation are considered to have a much higher commercial value.[7] Interestingly though, Dutch DSOs suggest that no large payments for flexibility should be expected from them, as generally, flexibility has *"relatively a limited scope and limited net benefits for DSOs"*.[8] This hints towards the challenging market deployment of energy storage which involves accessing and monetising the multiple value streams, making sure that all parties can clearly see its value and pay, and be remunerated for the benefits it offers. More importantly, local energy storage clashes in large with the existing regulatory framework. Factors like the lack of definition of energy storage, the unclear ownership rights, as well as issues like double grid fees and taxation prevent its deployment in Europe.

Energy storage is not a one-way street, though. Conventional wisdom suggests that renewable energy needs storage options. While it may be true that a completely renewable energy system would need mechanisms to balance supply and demand, it is not clear whether energy storage would be the preferred method for balancing the variable renewables and avoiding grid reinforcement. Power-to-heat systems, demand-side management or increased flexibility on the generation may play large role. Some countries are actually seen to expand their storage capacity and increase at the same time flexibility in their generation pool. In Germany for instance, where the penetration of solar PVs is high, the owners of such solar systems, instead of investing in energy storage, have also the possibility to choose to receive an addition of 1-2 cents on top of the main feed-in tariff for safeguarding a maximum of 80% of their capacity, allowing the network operator to curtail the rest. The need for a systemic approach to energy storage becomes, thus, crucial, as it helps bridging technical, regulatory, market and political aspects together. Actually, from a transition perspective, it can be argued that the alternative balancing solution that will dominate in the future energy system, will be determined to a certain extent by its compatibility with the overall institutional framework.

Alliander is an organization working on and for a reliable, affordable and sustainable energy system. While the total of sustainable energy in the Netherlands only rises to 5.8%, the amount of variable renewables in the country is expected to grow in substantial levels in the future, increasing in parallel the need of the organisation for greater flexibility that will enable it to meet its threefold mission. For this, Liander, the part of Alliander responsible for the network operation, launces test areas (pilots) to build its own knowledge and expertise.[9] One of these test areas concerns a neighbourhood battery, the Buurtbatterij, and the deployment of decentralised energy storage.

Using Liander's neighbourhood battery as a case this report presents the main findings from an exploratory research on the impact of local energy storage in the context of the energy transition. Aim of the researcher's part-time placement within the organisation was to assess the potential transformative impact of the concept of a neighbourhood battery. The case of the neighbourhood battery is interesting in three levels. First, it is interesting as it may offer a solution to future gird problems. Second, it is interesting because it may function as a vehicle for organisational change in terms of value creation and supporting actor networks. As third,

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[7] ITRE, 2015. Energy Storage: Which Market Designs and Regulatory Incentives are needed? http://www.europarl.europa.eu/studies

[8] FLEXNET, 2017. The supply of flexibility for the power system in the Netherlands, 2015-2050. Report of phase 2 of the FLEXNET project

[9] See also Appendix A for the relation between Alliander and Liander.

the concept is interesting because it functions as a disruptive element that physically connects top-down and bottom-up developments in the context of regime destabilisation and emergence of alternatives in the energy transition. In that, the battery encompasses a strategic innovation.

For this, the researcher investigated the perspectives of people within Alliander as well as those of a number of people active in energy cooperatives in the Netherlands, which may not be currently involved in the pilot but may have an interest (or not) in doing so in the future. Moreover, the researcher contributed to and got access to a survey on the perspectives of the users of the neighbourhood battery pilot. Overall, the focus was on identifying the central questions and insights that the concept presents, and in relation to these, the (social) innovations that emerge in the context of the energy transition. This work wishes to facilitate reflection that can help give focus and direction for a strategic engagement in the current energy transition context.

2. Research framework & Methodology

Research framework

The transition to a smart and sustainable energy system is not self-evident nor obvious. Transitions are long and complex social change processes in which construction and destruction take place simultaneously. How the future energy system will eventually look like is uncertain, and actors prepare themselves being proactively or reactively engaged with the changes taking place. The initiative of the neighbourhood battery involves multiple interests. From the avoidance of a future investment in grid reinforcement by the network operator to the increase of renewable energy initiatives' project portfolio value or (the expectation of) decreased energy bills for energy end users. Its value becomes especially visible to the latter two stakeholder subgroups, as the energy transition progresses, and policy measures like net-metering or the priority access of renewables to the grid may change. From an analytical perspective it is interesting to note that the actors involved in the development of such a collaborative business model have different values, structures and practices. Yet, a neighbourhood battery is also a physical connection point between top-down and bottom-up and comprises, as such, a type of transformative social innovation.

For the assessment of the transformative impact of the concept of a neighbourhood battery, this research builds on the conceptual framework developed as part the researcher's PhD. The framework combines a business model perspective with sustainability transitions theory and systems thinking. When focusing on value creation, beyond the narrative level, the actual practice of the organisations involved is important: the specific partnerships they build and the value exchange between them, as well as the specific products or services they develop; they may all have a certain impact on the system. To operationalise the latter for the mapping of the dynamics between innovation and its institutional context, we build on transition theory, which suggests the following dimensions (Smith and Raven, 2012[10]; Proka et al., forthcoming[11]):

1) Technologies and Infrastructures: the material dimension required for the societal function including all the technologies and physical infrastructures;
2) User Practices: the application domain of the concept or technology, and the associated new routines and norms of the actors;
3) Cultural symbolic meanings: the symbolic representation of the functioning including the associated values and guiding principles;
4) Knowledge base: involving scientific as well as tacit, practical knowledge associated with the societal function;
5) Sector Structure: the organizational networks, the particular sector capabilities and the specific interaction platforms for coordination and negotiation within the sector;
6) Policies and Political Power: the regulations, including the support framework, and the political power exercised to influence or maintain them, and
7) Organisational logic and structure: the specific logic of how an organisation generates value, including organisational decision-making processes, routines and activities

[10] Smith & Raven, 2012. What is protective space? Reconsidering niches in transitions to sustainability. Research Policy, 41(6), 1025-1036.
[11] Proka, Hisschemoller, Loorbach, (forthcoming). Assessing the transformative potential of renewable energy initiatives: a framework based on business model and sustainability transitions literature. Submitted to Research Policy.

directed towards the achievement of organisational aims, along with issues regarding ownership and the relationships between investors, producers and users.

The introduced framework also enables organisations interested in contributing to the sustainable transformation of the energy system to increase their impact by developing strategies to play into specific system dimensions.

Research method

The research took place between April and July 2017. Having reviewed academic literature and professional publications in relation to energy storage, a total of 17 interviews was conducted. This involved 10 interviews[12] within Alliander from a variety of departments and positions as well as an interview with the director of the renewable energy organisation involved in the pilot. In addition to this, driven by the hypothesis that in the context of an advanced energy transition local energy storage would be a valuable asset for renewable energy initiatives, as net-metering might not be applicable and renewable energy might lose its preferential treatment vis-à-vis curtailment, the research also involved the directors of 6 local renewable energy cooperatives which were not involved in the project. Concerning the latter, the focus was on including a variety of organisations in terms of level of professionalization, but also in terms of specific experience with energy storage technologies. During this period the researcher also contributed and got access to the results of a first survey pursued by Alliander on the end users of the pilot about the values they gain and the concerns they may have about the pilot.

Alliander ecosystem

The research within Alliander encompassed three areas. First of all, the research focused on the case of the neighbourhood battery and the interaction with the broader ecosystem of the organisation. Next, the focus shifted towards the possible impact of the neighbourhood battery on the business models of renewable energy initiatives. Last, the research explored how the project of the neighbourhood battery is positioned in the context of the energy transition, with the use of the X-curve.

The first area included a Cost/Benefit analysis of the neighbourhood battery, an analysis of the current barriers for its deployment, as well as a SWOT[13] analysis for the deployment of the battery within Liander. The Cost/Benefit analysis was conducted with a broad orientation on value that allowed the consideration of social and environmental values (and disvalues). The SWOT focused on the strengths and weakness of the company's *internal* environment (capabilities and resources) and how these relate to the deployment of the battery, and on the perceived opportunities and threats, as well as the current barriers located in the *external* environment of the company.

Secondly, the research explored possible ways in which the neighbourhood battery could influence the business model of local renewable energy initiatives. Although currently only applied on a social business within a pilot context, the interviewees were asked for their initial thoughts and ideas for the application of the concept beyond the pilot conditions.

As last, after a very brief explanation of the X-curve and what it represents, the interviewees were asked to position the pilot project on the graph and justify their choice. The X-curve has been introduced as a tool to discuss the dynamics that play out and the roles that different actors, people or organisations, take on in the context of sustainability transitions. While the tool is based on academic insights on how complex systems change, positioning an actor on the curve is always subjective and thus, the aim here was at mapping the different perceptions

[12] One interview involved 2 people, while another interview was split in two meetings.
[13] Stands for Strengths, Weaknesses, Opportunities and Threats.

of the employees of Alliander regarding the contribution of the pilot to the energy transition and the interaction between the top-down and bottom-up dynamics.

Pilot organisation

To further understand the neighbourhood battery concept and how it currently works, the organisation involved in the pilot was contacted. Tegenstroom is a local renewable energy company in Rijsenhout, which functions as an ESCO for the solar panels linked to the neighbourhood battery. The interview with Tegenstroom focused on the motivation for the involvement in the pilot, the value the organisation and its clients gain from the neighbourhood battery, the positioning of the project on the X-curve, and the impact the battery has on the energy system. Moreover, through communication with the company, access was given to the first survey focusing on mapping the initial thoughts and expectations of the end users in relation to the battery.

Renewable energy cooperatives

Principally this part of the research aimed at exploring the impact that local energy storage could have on the initiatives' business model, and the role and strategies of the initiatives therein. Since most of the directors of the cooperatives interviewed, were not familiar with the neighbourhood battery concept, the interviews began with the discussion on the cost and benefits of energy storage in general. The directors were then asked whether a neighbourhood or a home battery would be preferable and why. Following they were also requested to name the selection criteria that influence their decision concerning energy storage solutions. As last, the directors of the local initiatives were asked about the barriers and opportunities they identify as regards the development of local energy storage.

Neighbourhood battery end users

The survey was organised by Alliander. The survey was prepared in collaboration with the pilot organisation and the researcher's feedback. Responsible for conducting it was the pilot organisation. About 58% of the total pilot participants (N=19) filled the survey in. It should nevertheless be pointed that due to delays in the pilot process, when the survey took place, the neighbourhood battery was not in operation.

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3. The neighbourhood battery

The pilot

With a capacity of 140kWh (125kW inverter), Liander's pilot for local energy storage is located at the neighbourhood of Rijsenhout in Haarlemmermeer, North Holland. The specific neighbourhood was chosen because the battery could be tested in combination with the solar energy produced locally. In addition to the existing solar generation in the neighbourhood, Tegenstroom has installed about 280 solar panels on the roof of a social housing building in the area.

The pilot allows the network operator to study the behaviour of the battery and the reaction of the network as the battery is loaded and unloaded with the locally produced solar energy. At the same time, the 35 project participants and customers of Tegenstroom are able to maximise the use of their own energy, as the excess electricity can be stored in the battery and retrieved when needed. This reduces the pressure on the power grid, which in turn allows Liander to maintain the network affordable and accessible to all. During the period of the pilot, the clients of Tegenstroom participating in the project receive a discount on their energy bill: the final amount rises to about €10 per month, including the solar panel fee.

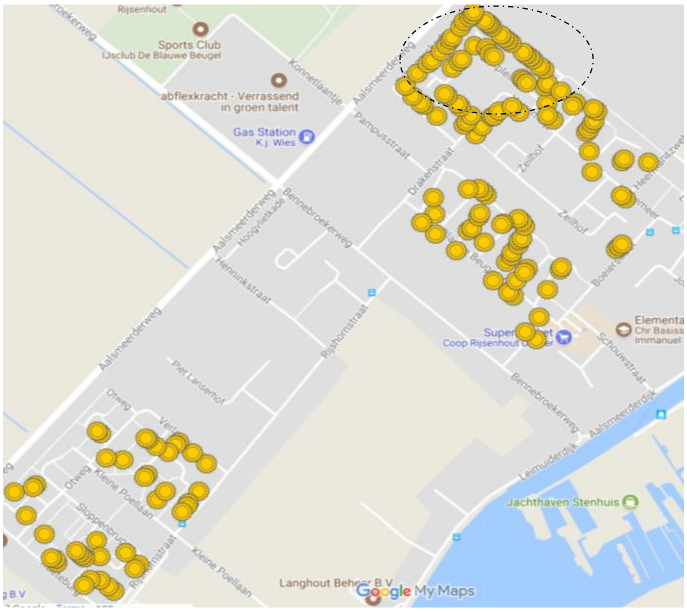

Figure 1: The solar generation capacity of Rijsenhout neighbourhood in Haarlemmermeer. The pilot area is surrounded by black dots (Source: Alliander google maps, 2017)

After coordination with the municipality of Haarlemmermeer, for this pilot, Liander is the owner of the battery, its management system, as well as the land where the battery is located. The access to the energy-related data was arranged in coordination with the local renewable energy provider, Tegenstroom, owner of the solar installation as well as the company Lyv Smart Living, which created the energy manager "Lyv Dash". The energy manager supports the end users in becoming aware of their energy production, while facilitating the optimisation of the use of their self-produced electricity consumption.

4. Renewable energy initiatives & local energy storage

Local energy storage

Since the integration of energy storage into local energy systems promises a number of benefits in energy resilience, increased affordability and economic opportunities for local communities[14], the research explored possible ways in which the neighbourhood battery concept could be used by different renewable energy initiatives and the impact it might have on their business model.

As a first step the initiatives were asked about the factors that consider as important when it comes to local energy storage. The battery's overall quality was put forward, that, in relation to both the issue of safety but also concerning characteristics like capacity and the speed to load and/or unload. The environmental performance of the technology was also mentioned as crucial, while the issue of noise was not thought as important. The issue of maintenance, though, was thought as principal, especially because the initiatives lack the experience around it. It is worth mentioning that cost was also a *silent* decisive factor. Although it was not voiced as such, the current high price of the technology was brought up when discussing the different barriers for the development of local energy storage.

Interestingly two opposing attitudes were found in relation to the decision-making process about local energy storage and its deployment by local energy initiatives. On the one hand it was pointed that direct communication with the people could address any possible resistance, concerning issues like aesthetics or noise for instance. On the other hand, nonetheless, others stressed that the preferable solution would come by people deciding themselves at local scale; the directors of the initiatives should facilitate the discussion and not try to advocate in favour of one solution.

As for the comparison between neighbourhood and home batteries, people involved in the initiatives argued that the former is seen as a preferable option. In fact a neighbourhood battery was seen as more efficient, cost-effective, and offering more capacity while also being easier for the grid operator. Yet they expressed their impression that, in practice, such a solution would require more effort in organising its arrangement and making it happen. Household-level energy storage on the other hand, was thought as involving too low energy capacity and too much administration for small organisations with lack of workforce, and therefore would not be preferred. It could thus be argued that at least for the initiatives approached, a neighbourhood battery could be a competitive energy storage option.

[14] Parra et al., 2017. An interdisciplinary review of energy storage for communities: Challenges and perspectives. Renewable and Sustainable Energy Reviews, 79, 730–749.

The concept's influence on the business model of renewable energy initiatives

As the area of local energy storage is an upcoming area, and the concept of the neighbourhood battery is only at a piloting phase, not many concrete ideas emerged with respect to the possible involvement of renewable energy initiatives in such a collaborative business model for local energy storage. What follows is the findings of the interviews with the people within Alliander and those involved in the different energy initiatives.

Network operator perspective

As regards the first, there was no clear thought about how such a collaborative business model would look like and in fact, as one interviewee pointed, this has been the case because Alliander has no interest in capitalising this market opportunity. Yet, not all interviewees shared this view. On this, it is worth mentioning that not all employees interviewed were aware of some ongoing exploratory discussions between some energy initiatives and the network operator on the topic.

Renewable energy initiatives perspective

When it comes to the initiatives, they principally focused on the additional benefits that energy storage involves, like the opportunity to increase the self-consumption of the locally produced energy, together with the opportunity to stabilise the financial return from it. For some, the main advantage was that the battery would allow them to continue with their current project plans, leaving their business model structure intact.

While some suggested that a neighbourhood battery would not have a significant influence on their overall business model, others argued in favour of the development of completely new business models focusing on making full use of the potential benefits that energy storage entails. For instance, some suggested offering services to the network operator by possibly only discharging the battery out of peak-hours (when the energy price is high).

In this way, the saved costs between the network operator and the initiatives could be split so that the later can pay back the battery to the former. Yet, some initiatives problematized the idea of acquiring such assets because of their maintenance cost and the need for specific technical expertise. For this, once could argue, that a collaborative business model, could possibly be preferable. Nonetheless, some initiatives pointed that local energy storage could enable the energy cooperatives or a cooperation between them to become Programme Responsible Parties themselves, being responsible for specifying how much energy they expect to feed into and take out of the grid each day.

On the interface with the end consumers, while the pilot circumstances enabled the provision of a temporary discount on the energy bills of the people involved, how this would look like beyond the pilot phase is uncertain. As concerns the practices or the end users, the interview with the pilot organisation and the survey hinted towards the lack of significant practical change at the level of the individual as a result of the introduction of the battery. Currently the participants may track their production and consumption and how much energy the battery has, but the overall battery management is done automatically.

5. Societal costs & benefits

To begin with, it worth presenting the research already done by the organisation on the issue of the societal costs and benefits of the neighbourhood battery. Liander pursued a comparative analysis of the true cost of grid reinforcement vis-à-vis the introduction of battery systems. The results are mixed. While cables performed better in the social dimension, batteries were found to perform better in the environmental dimension. The latter can be explained by the amount of materials required for achieving the respective support of the grid with a possible grid reinforcement, as opposed to the introduction of energy storage systems.

Table 1: Impact assessment of neighbourhood battery (source: Liander)

Financial impacts (- -) Battery purchase; Maintenance (-) Connection; Housing; Losses; Measurement costs; IT (+) Delay aggravation; Market value of houses or neighbourhoods (++) Market share yield (trade) (+ + +) Consumer yield
Natural impacts (- - -) Energy losses (during use phase) (- -) Material or raw materials: during extraction / processing / production: (Cable: plastics, metals. Battery: battery, plastics, metals, rare earth, toxic substances) & during waste phase (recycling and waste, modular construction battery) (-) CO2 footprint / CO2 coefficient of raw materials; Transport (+) Climate change; less impact in comparison to the placement of a larger transformator in case of aggravation
Social impacts Safety 0 (+) Social cohesion; Quality space / environment / living environment; Coolness factor / Battery Hype; Jobs / Labour; Health; Help neighbours (energetically) / cooperation / togetherness; Caring for the customer / Dependence only; Sustainability (++) Reliability / Delivery Security; Customer comfort / customer satisfaction; Malfunctions / failure / peaks / congestion / PQ problems occur
Intellectual impacts (+) Educational / awareness; Avoidance of future development costs; Acquire customer knowledge; Stimulates solar panels, after investment payback (++) Knowledge / experience about alternatives; Obtain experience with shared use algorithms (software); Accelerate energy transition (keeping supply and demand in line with) renewable energy, local growth, innovation, other market structures / market models, renewable energy)

The organisation has also performed an initial mapping of the possible positive or negative impacts of the neighbourhood battery, as shown in Table 1. Yet, the analysis is not thorough. For instance, it is suggested that the battery will have a positive impact on the social cohesion at the neighbourhood. Nevertheless, the relation between the installation and its impact on the social environment is not so straightforward, as it depends on a variety of factors. In fact, the preliminary results of the first survey involving 19 out of the 35 participants of the pilot, do not validate this hypothesis.

Societal benefits

The positive impact of the neighbourhood battery was investigated from the perspective of the network operator, the renewable energy initiatives, as well as the end users involved in the pilot.

Network operator perspective

From the perspective of the network operator the societal benefits can be grouped in three categories: a) benefits for the network operator; b) benefits for a commercial party and c) benefits for the end user.

In the first group, the benefits mentioned refer to avoiding a *future* problem, when both the diffusion of renewables and the energy consumption are going to be higher. For this, increased flexibility was mentioned as the main benefit offered. Flexibility is thought as valuable for grid capacity support, allowing balancing of possible congestion, and for voltage control. Both are expected to improve power quality.

Such a local energy storage solution may allow Liander to either prevent or postpone the investment in cables for low-voltage systems. In fact, local energy storage in the areas that this is required was seen as a possibly cheaper solution compared to grid reinforcement. What is critical here is that the final effect depends on whether the grid reinforcement will need to anyway take place in the end. In addition, it is argued that this option will be less of a hassle for society, than reinforcing the grid.

As last, it was mentioned that the neighbourhood battery offers the opportunity for the network operator to better connect with its own clients and also improve its general relations with the public.

For the commercial party, the value offered relates to the possibility to enter the energy market and trade both in the capacity market as well as the frequency market. In the case that the party engages in renewable energy production, this may also enable taking a precautionary stance against very low or even negative prices for the energy generated.

From the perspective of Liander, the value the neighbourhood battery may entail for the end user relates to issues like autonomy, seen as the use of "own" green electricity (on the grid), energy security, power quality, (possible) tax advantages, protection from negative prices for self-generated energy, but also contribution to social cohesion and to consciousness about the value of energy.

Lastly, the people within Alliander mentioned other benefits which are actually *relative* benefits of the concept compared to household level energy storage. The neighbourhood battery is seen as cheaper, using less material, and reaching higher efficiencies, offering a safer than the in-house energy storage alternative. And of course the system of Liander helps avoiding the need to buy a battery or store it one's house.

Renewable energy initiatives perspective

Moving towards the perspective of the different energy initiatives contacted, the principal value of energy storage was seen as contributing to the progress of the energy transition. This either now, by directly supporting the network enabling the initiatives to proceed with their project plans and accelerate the energy transition, or in the future, by functioning as a backbone in an energy system dominated by renewables. The introduction of storage takes away the "*what if the wind don't blow*" argument, as pointed.

Moreover, financial benefits have been mentioned. On the one hand the initiatives are assisted in "stabilizing" their energy price but also, on the other, they are enabled to take a more “aggressive” stance engaging in energy trading for maximising the value they get from their investment. For the latter the interviewees suggested that they could do it either on their own or through the energy utilities they are currently collaborating with.

A neighbourhood battery is expected to help securing the future energy system, as the system is currently already secure. The initiatives anticipate that the use of local energy storage will result in lower network costs, which in turn are thought to result in lower energy prices for everyone. At the same time, nonetheless it was suggested that members of local renewable energy initiatives would even be “*willing to pay a bit more for using own local energy*”.

Other benefits associated with the introduction of a neighbourhood battery, relate to the support of their vision for energy autonomy, ownership and control. Becoming co-owner of the facility “*you make it* (i.e. the transition) *happen*”. In addition, the introduction of a battery to their system is believed to also contribute to the initiatives’ image, although the initiatives “*already have good image*”, as they point.

End user perspective

Interestingly, after the installation of the neighbourhood battery, 84% of the survey participants thought that they would need to pay less for their energy bill. On their practices, while 90% suggests that they monitor more often the production of their solar PVs, about 68% point that they did not take additional energy saving measures since. Moreover, 74% of the participants argue that they do not engage in more discussions with their neighbours. Yet, 79% of the participants expect more neighbourhood batteries in the future.

Societal costs

While the perspectives of the network operator and the different local energy initiatives on possible societal costs of the neighbourhood battery have been consulted, the end user survey did not include any question in relation to this issue and therefore their perspective on the topic is missing.

Network operator perspective

Turning to the societal costs, the matters pinpointed by the employees of Alliander touched upon, material issues, like recyclability and possible environmental damage due to the difficulty of recycling, and energy losses due to low efficiencies. In fact, the intensity of use across the battery’s lifecycle is expected to further exacerbate these efficiencies.

Another important cost factor mentioned was the issue of space, especially in the densely populated cities of the Netherlands. In addition, concerns about the battery’s appearance, the emission of a soft noise, or issues related to maintenance and safety were also mentioned as possible costs of the concept.

It was also argued that a possible decline in the collection of tax, due to higher energy self-consumption of those able to produce their own energy, could result in higher “socialisation of costs” for those who cannot.

Renewable energy initiatives perspective

The different issues mentioned by the renewable energy initiatives concerned matters of use of rare minerals and fluids, the impossibility (to their eyes) to recycle batteries, issues related to space and appearance, as well as safety and maintenance. The issue of maintenance of a battery was actually seen as important for the cooperatives that lack this type of expertise.

Interestingly, when discussing social costs with the directors of the local energy initiatives, some expressed the inability to come up with issues. Pointing is the fact that, one director mentioned that in relation to their goal towards self-sufficiency, *"one important step is storage… so I can't think of any social costs"*. Yet, in opposition to this, beyond the impact on their immediate environment, other directors brought up the issue of social sustainability and the conditions in the country of production of the material used for the batteries.

Contrasting the perspectives

At first glance one may notice that, compared to the directors of the renewable energy initiatives, the network operator sees more value for the concept, and that for more parties involved: for commercial parties, for the end user and, naturally, for the network operator. The former, apart from the broad general value of the support to the energy transition and the secure and cheaper network, mainly come up with possible benefits for themselves, which range from energy autonomy to financial benefits. The same pattern is also visible when assessing the possible costs of the neighbourhood battery: people within Alliander come up with more issues. This may be the result of their experience and relevant expertise, especially since the majority of societal costs are associated with the technical elements of the concept. It should be stressed that, while people within Alliander are more familiar with the concept, the topic is new for the people involved in the energy initiatives and thus, they lack a clear picture as regards its costs and benefits.

Concerting the overall benefits of the neighbourhood battery, it could be argued that part of the benefits mentioned by the network operator cannot currently be felt as such by the majority, because they relate to already existing features of the system, like for instance power quality. Similarly, the positive value concerning the image of the initiatives may also not be felt as such. Also, some of the other benefits mentioned by the network operator are *relative* values of the neighbourhood battery. This means, that these values may only be relevant for those who are currently considering household-level energy storage. Lastly, regarding the suggested positive contribution of the battery to social coherence, as already pointed, the cause and effect relationship under discussion is not clear. The final impact depends on several external parameters, like the existing level of community feeling, as well as on the overall process through which the battery will be positioned and managed. And in fact, the first end user survey documents no influence on their interaction pattern with their neighbours. Also, while more positive environmental impact is expected by them as a result of the battery introduction to the system, no such impact has been registered. What is important to note is that the end users are in great extend expecting that the neighbourhood battery will have a positive impact on their energy bills.

As for the societal costs of the concept, more issues relate to its technological features. Among them, the difficulty of recycling batteries, while certainly being challenging15, is perceived as absolute impossibility by some people of the local energy initiatives. Interestingly when discussing the costs with a more social nature, the representatives of the energy initiatives focus on different things than the people within Alliander. The former focus on the social sustainability of the technology across the entire value chain, especially referring to the societal impact at the countries where the extraction of the minerals required for the batteries takes place. For this specific point, their attention goes therefore beyond their immediate environment. The latter on the other hand, focus on the impact locally, mentioning the possible indirect effect of the technology on the national budget. What is being suggested is that higher self-consumption of energy will result in a decrease of the energy tax revenues, which will impact the broader society.

Concluding, it is worth stressing that the expectations about the neighbourhood battery differ between the parties involved. The different renewable energy initiatives and the pilot end users expect that the introduction of the neighbourhood battery will result in lower energy prices for

[15] See also Appendix C on the end-of-life management of energy storage systems.

everyone. Yet, according to the network operator this is not necessarily the case. Important is to also point that the values considered by the network operator, the renewable energy initiatives and the end users are not always in line. While the initiatives seem to prioritise the possibility of using storage for the stabilisation of the price they receive for their produced kWhs over the possibility of entering the energy trade market for profit, in case the latter happens, the neighbourhood battery might result in more congestion on the network, cancelling the hopes of the network operator in that regard.

6. Current barriers

At this part, the barriers mentioned by both the employees of Liander and the managers of the renewable energy initiatives will be discussed. Drawing on the research framework, the issues mentioned have been grouped in relation to the system dimensions they relate.

For the network operator, one of the first areas of barriers relate to the policy domain. The current legislation on the one hand doesn't allow Liander to own and operate a battery. On the other hand, the existence of the net-metering and tax arrangement regulation doesn't make the energy storage an attractive solution for the end user.

And indeed, the principal issue from the perspective of the energy initiatives is that the existing regulatory framework does not offer additional value for the introduction of energy storage. Other barriers on the policy domain relate to their concerns around the issue of taxation and how it will develop, as well as any possible requirement for specific special permits. In fact, for the current pilot it was mentioned that receiving a permit from the municipality was difficult because the whole concept was completely new for the civil servants responsible and no clear rules existed about how decisions should be made.

On the level of organisational logic and structure, also related to the overall sector structure, barriers relate to the vagueness in roles and responsibilities, the divided ownership and control, as well as which market party will have the right for first ride on asset. Related to this is also Alliander's focus on full network stability and the complete control of system assets. In addition, the lack of social business case and the lack of clarity on the involved financial transaction was seen as a bottleneck, together with the overall uncertainty about the development of energy prices.

The uncertainty about roles and responsibilities is also central for the renewable energy initiatives: who owns, controls and who does maintenance of the energy system? The issue of financing such a concept involving different partners was mentioned as very complex. In addition, crucial for the initiatives is the overall cost/benefit distribution across the value chain, starting from the countries of production to the specific location where the battery is going to be positioned. On for the latter, it was mentioned that rational arguments combined with sufficient financial benefits will be necessary for the deployment of the concept. As one of our interviewees pointed *"anything that has to do with making the energy system better is interesting - as long as there is a business case behind it."*

As regards technology and Infrastructure, from the perspective of Alliander the concept is seen as still "*pricy*" and not necessarily involving CO_2 emissions reduction across the entire life-cycle.

For the local initiatives on the other hand, the existing energy storage solutions are indeed seen as too costly for the value they return. For them, the overall social and environmental cost/benefit distribution across the entire value chain is crucial and the "*ethics question*" is still open. As last, another barrier mentioned by the local initiatives relates to the level of control of the battery and the technical unfeasibility to deliver energy from one specific source to specific end users, at the level of kWh produced.

Turning to the side of the consumer and the user practices, the existence of low (if any) societal interest on the topic of energy storage, linked to issues about safety and health concerns (about possible radiation), or privacy (about smart meters connected to them) are seen as barriers. At the same time, the assumption is voiced that consumers have preference for household-level batteries. Aesthetics also play a role. In fact, an employee of the organisation pointed that local governments do not want to sell land to the organisation "*because they make it ugly*", which in turn also creates an organisational issue.

Seen from the perspective of the initiatives, a main barrier relates to peoples' general lack of awareness and consciousness about energy: "*people are not aware that we are using the grid as a big battery*". And beyond matters of space and aesthetics, the existence of a low frequency noise was mentioned as another barrier, along with concerns about safety.

To conclude, when it comes to the barriers identified, people involved in the different initiatives seem to be in line with the people within Alliander. Both sides see multiple barriers for the development of local energy storage. It could be argued that the vagueness of the regulatory framework is felt as the principal factor hindering the deployment of the neighbourhood battery concept. When the framework allows different actors may invest time and effort to develop the currently lacking alternative business models, negotiating the distribution of costs and benefits and clarifying the roles and responsibilities of the different parties involved**.**

Present policy landscape

Under the current energy law the use of energy storage by a network operator like Liander is only permitted if the installation is only used for the network operator; no shared use of a battery is allowed. Connecting a battery to a solar PV and deploying it in an energy market is in violation of the Group Prohibition (Article 10b of the Electricity Act) and the Prohibition of Competition (Article 17, first paragraph, E-Law).

At the same time, the so-called "Winter Package" is currently under negotiation at the European level. Among other parties, the network operator negotiates its access to owning and operating energy storage systems. Table 2 presents the current policy landscape in the EU.[16]

Table 2: Policy landscape in the EU

Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on common rules for the internal market in electricity (recast) - Article 36: Ownership of storage facilities
1. Distribution system operators shall not be allowed to own, develop, manage or operate energy storage facilities. *2. By way of derogation from paragraph 1, Member States may allow distribution system operators to own, develop, manage or operate storage facilities only if the following conditions are fulfilled:* *(a) other parties, following an open and transparent tendering procedure, have not expressed their interest to own, develop, manage or operate storage facilities;* *(b) such facilities are necessary for the distribution system operators to fulfil their obligations under this Directive for the efficient, reliable and secure operation of the distribution system; and* *(c) the regulatory authority has assessed the necessity of such derogation taking into account the conditions under points (a) and (b) and has granted its approval.* *3. Articles 35 and Article 56 shall apply to distribution system operators engaged in ownership, development, operation or management of energy storage facilities.* *4. Regulatory authorities shall perform at regular intervals or at least every five years a public consultation in order to re-assess the potential interest of market parties to invest, develop, operate or manage energy storage facilities. In case the public consultation indicates that third parties are able to own, develop, operate or manage such facilities, Member States shall ensure that distribution system operators' activities in this regard are phased-out.* (source: http://eur-lex.europa.eu)

[16] See Appendix D for proposed business model specifications for DNO ownership and operation of storage assets as discussed in the literature.

7. Strengths & Weaknesses of Liander vis-a-vis the neighbourhood battery

For this part of the research only the employees of Alliander were consulted. The interviewees were asked to focus on the strengths and weaknesses of the organisation and explain how they relate to the deployment of the neighbourhood battery.

With its assets "*literally connected to society*" Alliander was presented as a pioneering and visionary organization, with plenty ideas, energy, funds, creativity and intention to work together with other actors. The problem solving capabilities of the organization have been put to the forefront, while the broad and deep knowledge and experience of Alliander with managing energy systems was introduced as a crucial strength of the company concerning the development of the battery.

When discussing the weaknesses of the organization as regards its ability to develop and support innovations, nevertheless, the organisational structure of the company came into focus. Used to pursue long-term investments with 40 years of assets cycles, Liander was depicted as cables "*cookiesfabriek*" (i.e. cookies factory), lacking structure as well as people with required expertise. Concerning the neighbourhood battery for instance, the organisation seems to lack people with technical skillset about battery safety and possible environmental costs, but also, customer contact and interaction.

Overall, the company is seen as too slow and too bureaucratic, with a lack of ability to absorb changes internally in the daily operation; the lack of a way to incentivise managers to embrace innovations was pointed as the biggest issue for the company. Moreover, the lack of transparency was also pointed as central and crucial for the development of innovations like the neighbourhood battery. It was argued that the company is scared of sharing information with the outside world, possibly because of the need to maintain the image of a "*very very reliable grid*". The focus on security and reliability, in turn results in lack of attitude for collaborative solution finding, with the participation of other stakeholders. It was even mentioned that it is as if the company wants to collaborate with other actors only when the latter follow the company's plan and ideas.

The image is thus mixed, with the company exhibiting the potential to develop, support and employ innovation and change, missing, nonetheless, a clear direction cutting across the organisational structures and providing orchestration of the different roles within and between the different departments.

8. Opportunities & Threats for the concept of neighbourhood battery

Both people within Alliander and the different energy initiatives were consulted about their perceived opportunities and threats for the deployment of the concept of the neighbourhood battery.

Network operator perspective

As central opportunity for the future deployment of the concept emerged the expectation for the net-metering regulation ("Saldering") to phase out after 2023, or significantly change by 2020.[17] The general progress in the Energy transition is an opportunity for the concept in itself as that would mean shutting down overcapacity, like coal, but also, that the current renewable energy support mechanisms, like the net-metering or the energy tax relief scheme ("Postcoderoos"), would approach their end time. Other opportunities raised by employees of Alliander relate to the decrease of the energy storage cost (this up to a level, since the neighbourhood battery competes with household-level energy storage solutions), or a possible increase of the market energy prices in the future. Technological developments like the emergence of smaller and more efficient batteries, yet having in mind again the competition with household-level energy storage, or social developments as the emergence of the need for energy independence, that remaining on-grid, were also mentioned as opportunities for the concept. In addition the possibility of using in case of emergency the decentralised batteries for "*Bottom-up black start*", that is the use of energy storage to restore the system after a black-out, as some electricity is needed which cannot be drawn from the grid.[18] In other words, local energy storage could be used to energetically support neighbourhoods when the national grid is not functioning. As last, the black-out fear factor was thought as an opportunity for the deployment of energy storage; what was argued, was that a less stable system could actually function as a facilitator for the deployment of energy storage systems.

Contrary to that, as possible threats for the deployment of the neighbourhood battery, issues that were mentioned include other possible technological breakthroughs, other potential financially preferable and more efficient solutions for the network operator, but also issues that relate to the consumers. For instance the possibilities of consumers shifting to own storage (at lower cost), getting off-grid, or remaining on the grid with the neighbourhood battery, yet using it to trade were considered as crucial. Furthermore, issues relating to the Alliander - consumer interface were seen as an important threat, like the possible emergence of conflict over battery ownership and steering. Lastly, the fact that the technology is not resilient to threats like possible natural disasters was also mentioned.

[17] The announcement of the government's programme clarified that in 2020 the mechanism will be adapted, making the local energy storage more appealing for the end users.
[18] EASE/EERA European Energy Storage Technology Development Roadmap, 2017 Update.

Renewable energy initiatives perspective

Seen from the perspective of the different initiatives, the possible phasing out of the net-metering regulation appears to be central opportunity along with the overall progress of the energy transition. When the transition advances, the increase in renewable energy is thought to demand more batteries as the backbone of the grid. What is more, the fact that batteries consist a tool for enabling the entrance to the energy trade market, is also seen as an opportunity for their development. The initiatives imagine that managing the neighbourhood battery their current suppliers or other commercial parties will enable them to also benefit from energy trade in the markets. At the same time they do not exclude the possibility of engaging in trading in energy markets themselves, transitioning in parallel towards becoming Programme Responsible Parties.

When it comes to possible threats for the deployment of the neighbourhood battery, the different people involved in the initiatives pointed to the general distrust on the technology, the low social acceptance towards it, as well as a possible decrease of electricity (production) cost to zero were mentioned.

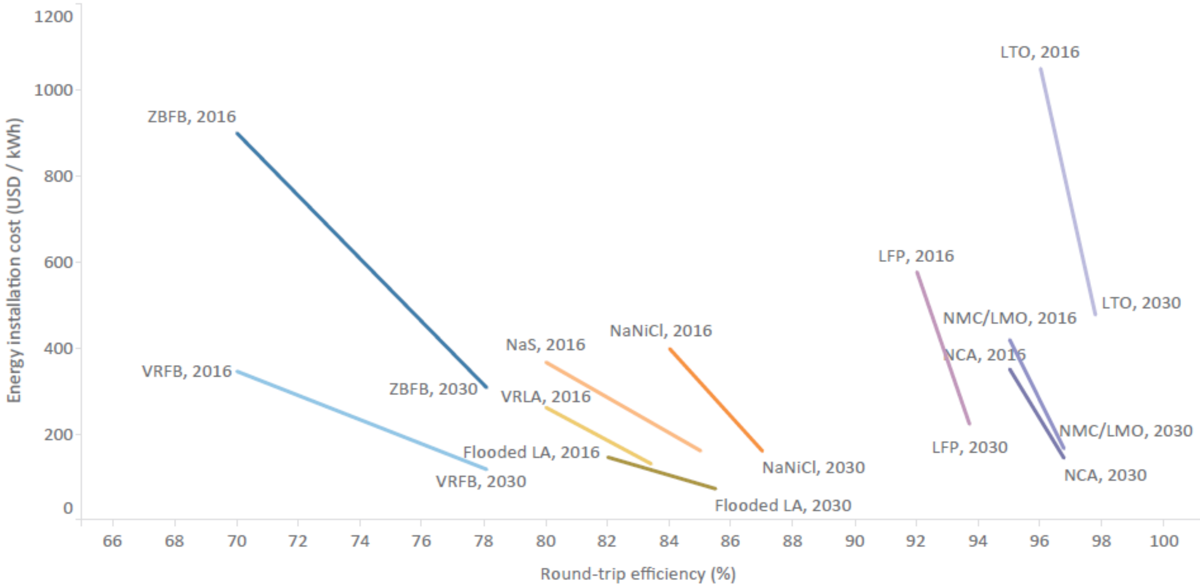

Figure 2: Energy installation costs and roundtrip efficiencies of battery storage technologies, 2016 and 2030 (Source: IRENA, 2017)

To conclude, the opportunities around the deployment of the neighbourhood battery appear to mainly belong to the policy domain, especially the phasing out of the net-metering regulation and more importantly the permission for the network operator to own, manage and control energy storage facilities. Technological developments are thought both as an opportunity and as a threat, as they may result in the deployment of more household-level energy storage. Interestingly, the side of the consumers and their practices is experienced as threat by the people within Alliander, while for the initiatives' managers, the threats are more positioned in the technological sphere.

One could argue that establishing trust and collaboration between the two sides could result in a better position for the concept as the partners can better take advantage of the existing opportunities while protecting each other against threats. This of course requires some negotiation between the parties in order to align their positions.

9. The neighbourhood battery in the context of the energy transition

The different employees of Alliander interviewed were asked to locate the project of the neighbourhood battery on the X-curve and justify their response. In this way, the researcher could map the perceptions of the different employees as regards the role of the concept in relation to the overall role of the organisation in the context of the energy transition.

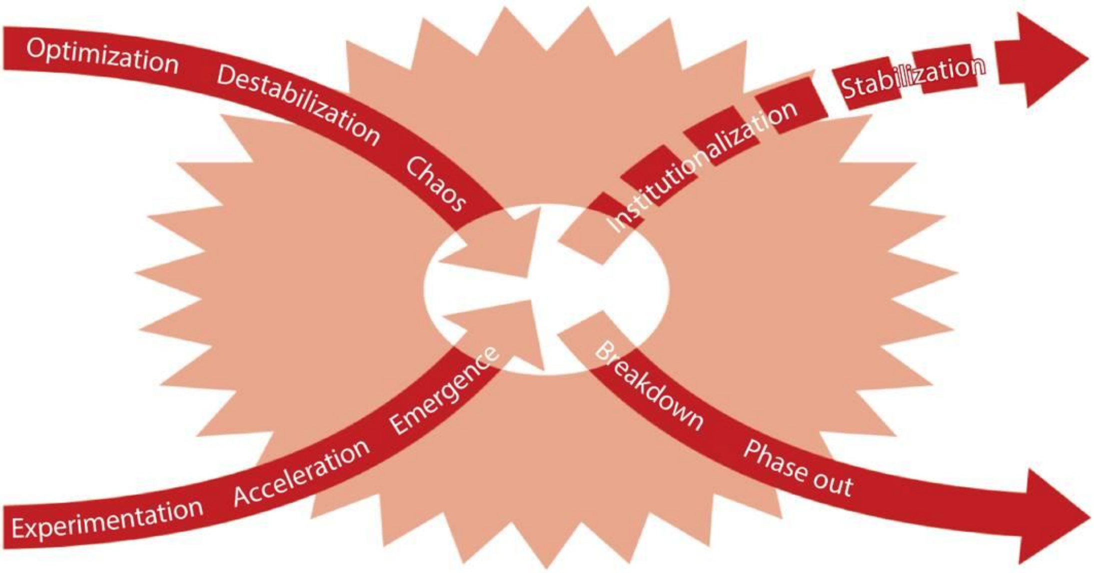

Figure 3: The X-curve (Source: Loorbach et al., 201719)

Most of the interviewees positioned the project on the experimentation phase, as the pilot involves testing completely different technologies, which require different ways of thinking and organising around the societal function of energy provision. Some people, argued that the project is slowly moving to the acceleration stage, which involves the emergence of new networks and partnerships. Interestingly, for some others the neighbourhood battery fitted under the optimisation phase, as the network operator is thought to be using the concept to improve its own position and the processes that is already involved in. As last, it has also been argued that the concept of the neighbourhood battery cuts simultaneously across both the experimentation and the optimisation phase: it is a new technology and overall process that, under certain conditions, may still support Alliander in its main purposes.

This exemplifies on the one hand the multitude of possible ways to implement the concept of the neighbourhood battery, and on the other, the hybrid nature of the organisation which may be present in the current as well as in a future sustainable energy system. The ultimate impact of the concept on the energy transition depends on the specific vision and strategy of the organisation and the outcome of the negotiation between the different parties involved.

[19] Loorbach et al., 2017. Sustainability Transitions Research: Transforming Science and Practice for Societal Change. Annual Review of Environment and Resources 2017, 42:1, 599-626.

10. Discussion & conclusion

Using the neighbourhood battery as a case, this research aimed at addressing the question of the potential impact of local energy storage on the energy transition. The neighbourhood battery has been studied as a strategic innovation, as it may function as a disruptive element that physically connects top-down and bottom-up developments in the context of the energy transition. In fact, the concept may also function as a vehicle for organisational change for the network operator. Therefore, the potential transformative impact of the neighbourhood battery was examined in two levels. On a first level, this research examined the values that the concept may create and how these values may contribute to the energy transition by influencing different dimensions of the system. On a second level, this research investigated the role of Alliander and its ability to deploy the concept of the neighbourhood battery.

There is no doubt that the potential impact of local energy storage on the energy system is manifold. While there is certainly value in the neighbourhood battery concept, ranging from grid support and power quality to the reduction of energy losses and the amplification of self-consumption, it is broadly acknowledged that its value will become more significant in the future. This research has shown that the perceived benefits of the concept differ among the parties involved and the value exchange between them is not necessarily aligned. Therefore, it is not clear how such a social business case may be developed. Divided ownership and control comes with uncertainty about the cost/benefit distribution and also the roles and responsibilities of the parties involved. It is unclear who is going to have priority over a shared asset: should the network operator have priority in times of congestion for instance? These type of questions need to be addressed.

When it comes to Alliander, while some might see the organisation as always being "*naughty*" looking for the boundaries of the law, as one of its employees pointed, it is undeniable that the organisation is actively involved in searching for solutions that support the energy transition. As regards the role of Alliander, and Liander in particular, on the specific project of the neighbourhood battery, when the external environment allows, it is not clear whether the organisation could indeed develop and maintain such projects. Apart from the fact that it currently lacks the expertise both in terms of technical skills for maintaining batteries and social skills for the contact with the customer, there seem to exist more structural issues that make the transition of projects from pilots to implementation difficult. The interviews documented a certain gap between innovation and operation, explained by the lack of a supporting structure coupled with real incentives for the managers to embrace innovation; this was pointed as "*the biggest issue for this company*".

This specific innovation involves collaboration with different parties, and while the organisation is considered to be "*cooperation intent*", things become more complicated in view of Liander's priority to maintain (the image of) a "*very very reliable grid*". The latter priority is in alignment with the acknowledged fear of sharing information with the outside world. In such a context, the organisations' high problem-solving capabilities, which could be considered as a strength, turn into a limiting factor as instead of engaging in the development of a business model for local energy storage in collaboration with the different actors involved, the organisation wants to top-down set the rules of the game.

Interestingly, Liander does not necessarily want to *own* the battery either, as long as it could *control* it in order to avoid possible system failures. As argued Liander's role is to maintain the network "*stable and trustworthy*" and giving access to the battery to market parties to trade could be possible, but only if it doesn't obstruct its core duty. In fact, it was mentioned that not being involved in the process would be preferable as long as the organization could "*make the rules so that the third party can come and do it*". Therefore, instead of collaboratively designing and carrying out a shared value creation for local energy storage, the ideal situation for the network operator appears to be as "*we will collaborate but we will tell you what to do*". [20]

Yet, the neighbourhood battery is a concept that depends on multiple parties for its materialisation beyond the pilot phase. For this to happen, the actors involved need to be able to capture sufficient value. In other words, the cost/benefit distribution should be appealing to all parties for them to join. This means, that if the network operator is interested in taking priority on the battery management in moments of congestion on the grid, its offer in return should be adequate (and clearly communicated) for the needs of the other parties.

While currently the legislatory framework does not allow the network operator to own or manage energy storage the ongoing discussions at a European level suggest that in the coming future the conditions may change enabling Liander to do so. For this reason, it is advisable that the network operator clarifies the different parameters that are crucial for its decision on pursuing or not the deployment of the neighbourhood battery. Having designed a decision tree, next step could be to map the different trade-offs that the organisation would be willing to make. This requires transparency in the negotiation processes and beyond, and consistency across the entire organisation about the chosen direction.

For such a collaborative value creation in the context of the energy transition, it is deemed worthwhile for the actors (to-be) involved in local energy storage both within and beyond Alliander to engage in dialogue for sharing their different perspectives. This is especially relevant as the present research discovered different levels of awareness and knowledge within and beyond the organisation regarding local energy storage. As mentioned, the value of energy storage will become more visible for end users and end user collectives when the energy transition progresses. The network operator could, for instance, incentivise deployment of storage in optimal locations in distribution networks offering providers useful information about demands throughout the network in the form of heat maps[21].

To conclude, the impact of local energy storage like a neighbourhood battery in the energy transition, or in other words, its transformative potential, relates to the different contributions it may bring to the overall system dimensions, like for instance sector structure or user practices. Its value may contribute towards the stabilisation of the current status quo or its radical transformation and the transition to a sustainable energy system. And in fact, while the points of friction with the current system may be seen as hindering its overall potential, it is these friction points that actually exhibit the potential for transformation. The fact that currently the concept conflicts with the existing regulatory framework and the dominant sector structure, as well as organisational logic and structure, may show that the concept exhibits potential for transformative impact. The ultimate impact on the system will be determined by the concrete actions taken by the actors aiming to circumvent the existing barriers and bring the neighbourhood battery concept forward.

It is for this reason that the main issue determining the potential transformative impact of the neighbourhood battery concept refers to the critical question of what the guiding principles behind the concept and its implementation are. What should the introduction of the neighbourhood battery stimulate? How should the decisions over the possible trade-offs be taken? Pursuing sustainability requires the articulation of tensions and dilemmas before the

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[20] It should be pointed that this statement is not endorsed by (all) the actors involved in the pilot. Instead it has been argued that the neighbourhood battery pilot has been established in order to explore how local energy storage could be organized cooperatively, as intended by the organisation.

[21] Gissey et al., 2018. Market and regulatory barriers to electrical energy storage innovation. Renewable and Sustainable Energy Review 82. 781-790.

critical decisions and actions are taken. And while a certain delineation from the state as regards the deployment of local energy storage will be assisting and facilitating, it is the organisation's vision therein which is vital.

Appendix A: Alliander & Liander

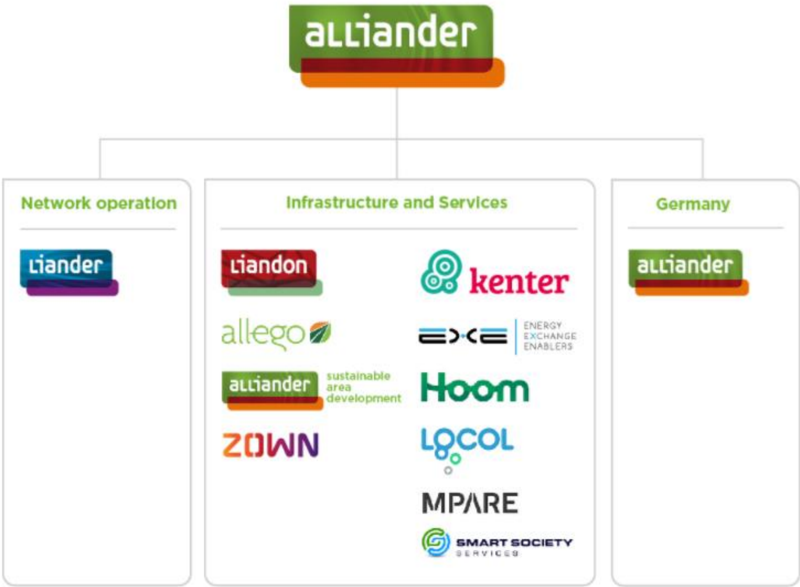

Figure i: The organisation (Source: Alliander, 2017)

Alliander is a public limited liability company committed to running a reliable, affordable and sustainable energy grid.

Its largest shareholders are the provinces of Gelderland, Friesland, Noord-Holland and the municipality of Amsterdam.

Primary task of Alliander is to distribute gas and electricity to consumers, businesses and institutions, ensuring safety and reliability in the process.

Liander is the network operator that makes this possible by taking care of the construction and maintenance of the electricity and gas networks in the areas that the organisation is involved. Specifically, Liander currently services more than three million customers in the provinces of Gelderland, North Holland, Flevoland and in many parts of Friesland and South Holland.

A second part of Alliander focuses on the development of new infrastructures or services. For instance, Liandon is concerned with developing sustainable technologies and intelligent energy infrastructures. Among others, the metering business Kenter offers innovative solutions for energy metering and energy management, while Allego provides charging infrastructure and services for electric mobility.

Alliander is also partly involved in the German network.

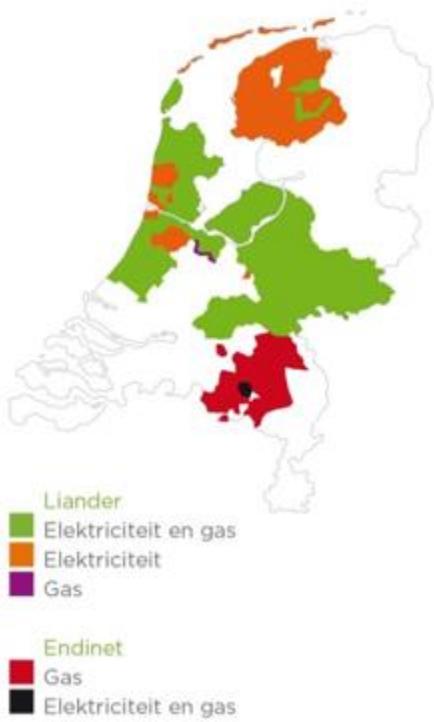

Figure ii: The areas (Source: Alliander, 2017)

Appendix B: Balancing market value

In preparation of the next stage of the energy transition, a number of countries are currently in the process of identifying the necessary market reforms required to support higher shares of variable renewable energy. This includes the development of markets for ancillary services to the electricity grid and the introduction of more granular markets to reward individual services more directly (e.g. primary and secondary frequency reserves).[1] Although still representing relatively small overall costs within the electricity system, these markets are expected to grow in importance and value.

For instance, in the United Kingdom, the market for balancing services represents an estimated market of GBP 1120 million in 2016/17 (and GBP 871 million for 2017/18) in comparison to the value of the wholesale market as a whole of GBP 577 billion in 2016/17.

Table i: Balancing market value in the United Kingdom by service, 2016/17 & 2017/18 (Source: IRENA, 2017)

Country	Total 2016/2017 (£ millions)	Total 2017/2018 estimate (£ millions)
Energy imbalance	-54.3	-8.5
Operating reserve	189.7	85.3
Balancing mechanism startup	6.7	3
Standing reserve	63.2	64
Constraints - England,Wales, Cheviot & Scotland	262.2	276.8
Footroom	24.5	7.9
Fast Reserve	93.6	119.6
Response	147.4	179.2
Reactive	79.2	77.9
Black Start	90.1	44.9
Minor components	21.5	20.5
Other	25.0	
Black Start - other allowances	53.9	
Supplemental & demand-side balancing reserve	117.4	
Total alancing system costs	1120.0	871.0
Estimated balancing service charge (£/MWh)	2.43	1.71

Appendix C: End-of-life management of energy storage systems

With the increased uptake of energy storage technologies, the availability of raw materials, especially for use in lithium-ion (Li-ion) batteries has gained much attention in the last few years. Some attention on the issue comes from a supply risk perspective. While it is acknowledged that the current risk does not appear sufficiently threatening to endanger the future uptake of the technology, it does point to the growing importance of sustainable end-of-life management strategies for energy storage systems that include effective recycling.[1] The development of end-of-life programmes that increase recycling, reuse, or remanufacturing methods for energy storage systems is of vital importance for an enduring positive impact to the energy transition.

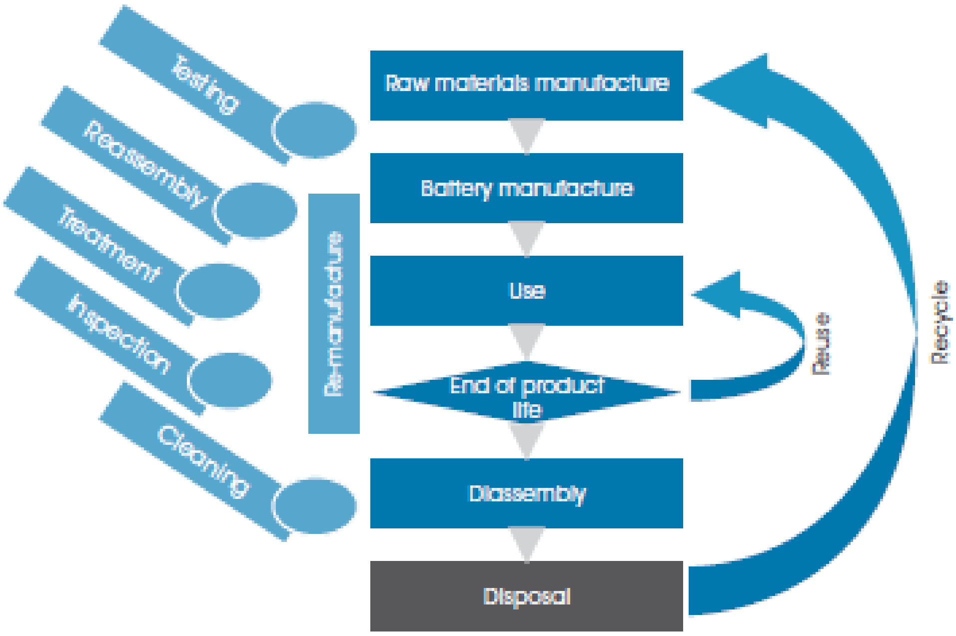

Figure iii: Battery electricity storage manufacturing and end-of-life flows (Source: IRENA, 2017)

Nowadays, the recycling of lead-acid batteries, for instance, is economical and widely undertaken reaching a recycling rate of more than 99% in Europe. At the same time, while progress in recycling methods continues and the interest of both academia and industry in seeking recycling paths for other chemistries is high, the diversity of Li-ion chemistries poses added challenges to their recycling.

Appendix D: Alternative business model specifications for DNO ownership and operation of storage assets

While currently prohibited by current regulations, five potential business models for distribution-scale storage have been proposed (mostly) by DNOs, and offer them partial or full control over storage assets.[19] They are enlisted in Table ii.

The major concern for models involving DNOs as merchants and, more generally, Distribution System Operator (DSO) business models, is to avoid distortion of competition in generation and supply and to respect unbundling requirements. On the other hand, such competition issues are less important in models related to incentives to charge, as a third party would be involved in both ownership and operation.

Table ii: Proposed business model specifications for DNO ownership and operation of storage assets (Source: UK Power Networks Electricity storage in GB. 2013[22])

Model	Description
DNO contracted	The DNO owns and has full operational control over the storage asset. Before the storage asset is built, long-term contracts are agreed for the asset's commercial control in certain periods of time.
Contracted services	The DNO offers long-term contracts for services at specific locations with commercial control in certain periods of time.
Charging incentives	The DNO sets the DUoS tariff to create signals that incentivize peak shaving to reflect the value of network reinforcement.
DNO merchant	The DNO owns and has full operational control over the storage asset.
'DSO' role	The DNO owns and has full operational control over the storage asset. In addition, the DNO is given a regulatory role in balancing and controlling aggregated demand and generation, taking on an active role as a Distribution System Operator (DSO).

[22] UK Power Networks, 2013. Electricity storage in GB. Interim report on the regulatory and legal framework smarter network storage low carbon network fund